Precision theory inputs for $|V_{cb}|$ and LFUV observables (LOI TF 010)

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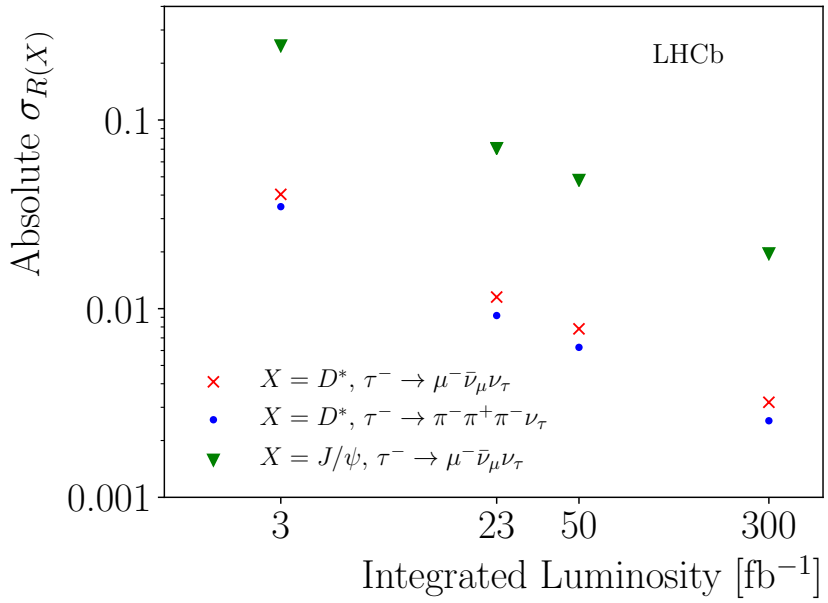
Getting to the bottom of B anomalies:

- Long-standing $|V_{cb}|$ inclusive vs. exclusive $\sim 2\sigma$ discrepancy
- Long-standing $R(D)$ and $R(D^*)$ $\sim 3\sigma$ combined tension
- Recent LHCb result for $R(B_c \to J/\psi) \sim 2\sigma$ tension

The constellation of anomalies in $b \to c$ transitions has attracted intense theoretical interest in recent years.

We can expect a trove of precision expt'l data within the *near-term horizon*.

- Belle II $\delta|V_{cb}| \approx 2\% \to 1.4\%$ by ~ 2025.
- Increasing precision of measured R-ratios:



- New channels LHCb 2020:

$$|V_{cb}| = 42.3(8)_{\text{stat}}(9)_{\text{syst}}(12)_{\text{ext}} \times 10^{-3} \quad \text{LHCb } B_s \to D_s^{(*)}$$

$$|V_{cb}| = 38.3(3)_{\text{stat}}(7)_{\text{syst}}(6)_{\text{lqcd}} \times 10^{-3} \quad \text{Belle total } B \to D^*$$

To leverage this data theory input should match experimental precision → ab-initio methods of lattice QCD required.

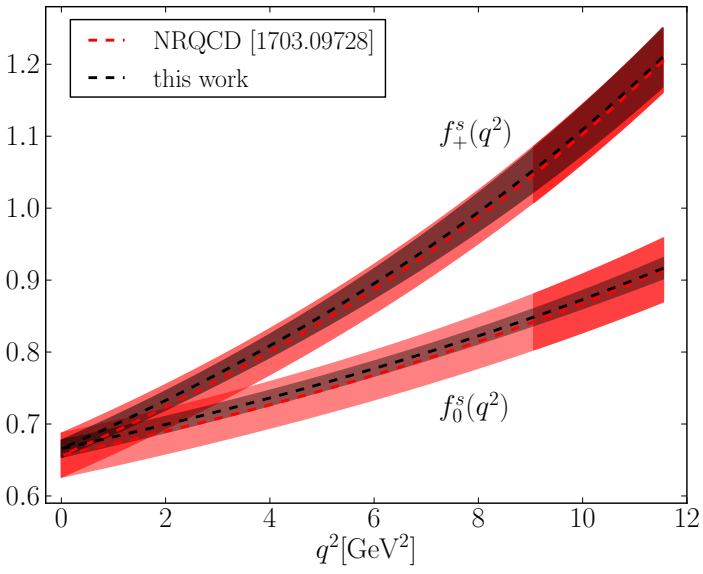
- Increase precision of $|V_{cb}|_{\text{excl.}}$.
- Work at nonzero recoil → reduce model dependence.
- Calculations in multiple $b \to c$ channels.
- Work on inclusive B-decays. see LOI TF 020 & talk by W. Jay
- Warrants close collaboration with experimentalists. see LOI RF 116 & talk by B. Dey

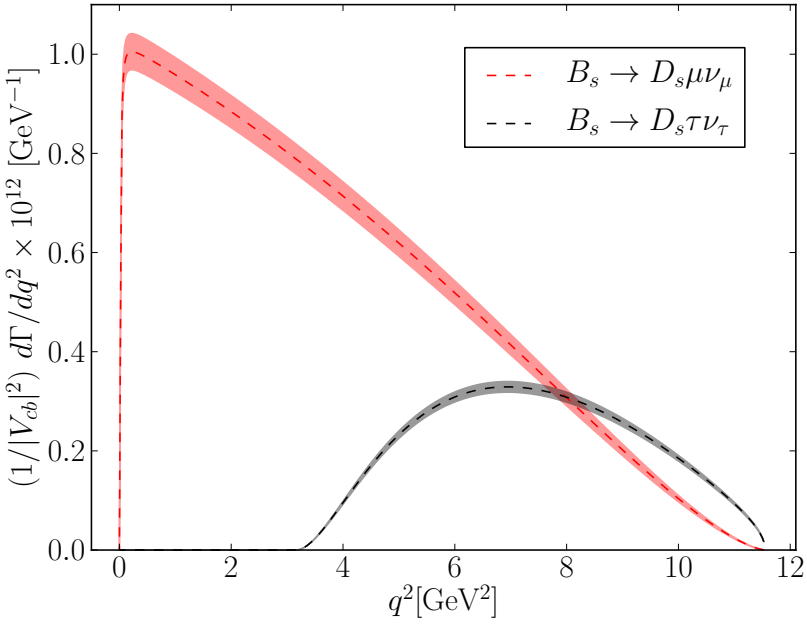
The lattice community both in the US and internationally has recognized the importance of these studies. [2004.01132]

Recent and upcoming work

- Multiple calculations of processes + improvements in precision/methodology.

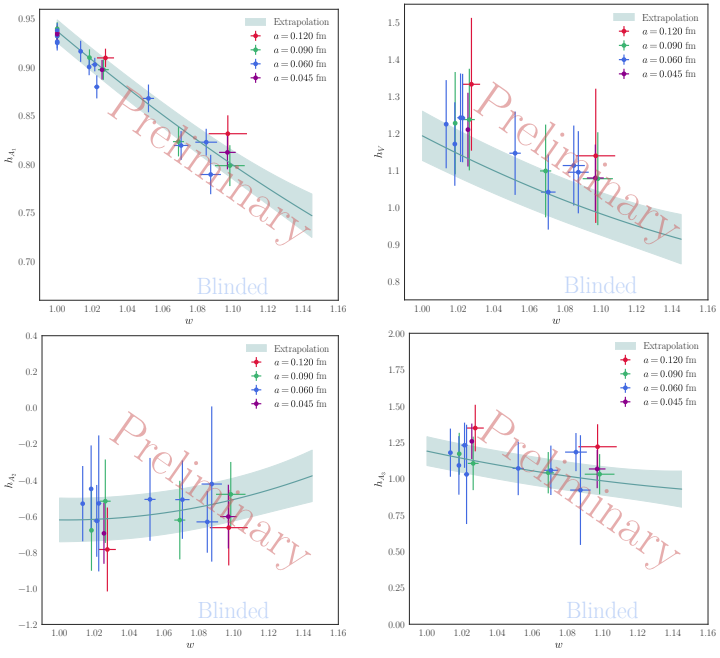
$B_s \to D_s$ over the full kinematic range: HPQCD [1906.00701]

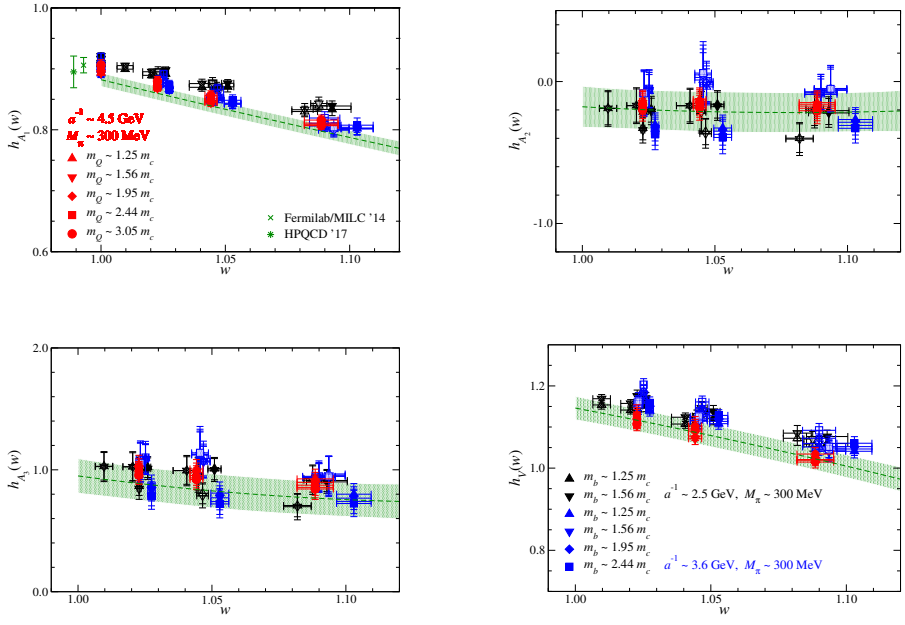




Used in first determination of $|V_{cb}|_{\text{excl.}}$ from $B_s \to D_s^{(*)}$ decay. LHCb [2001.03225]

- $B \to D^*$ at away from zero recoil. (preliminary)



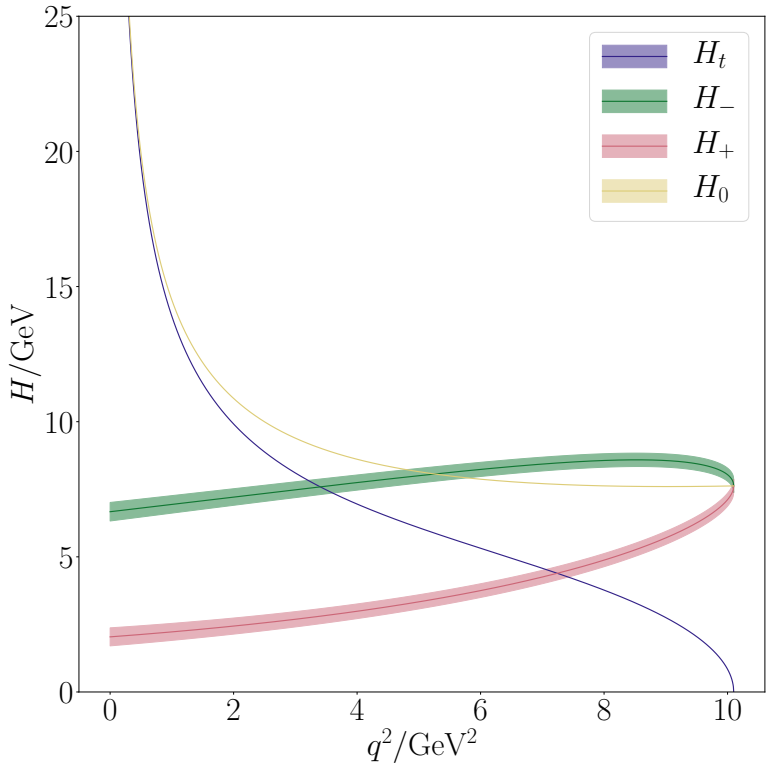


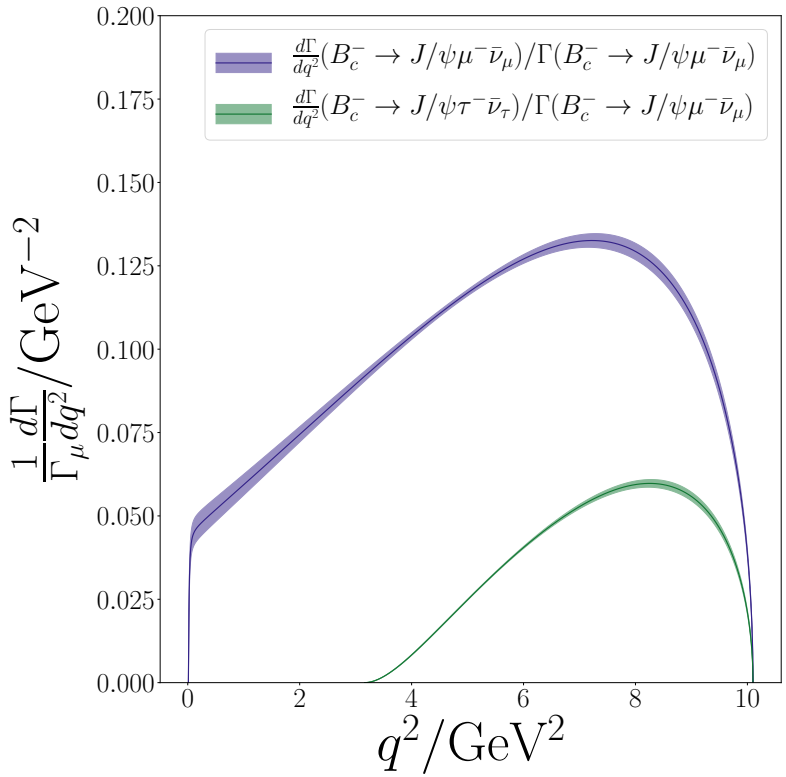
FNAL-MILC [1912.05886]

JLQCD [1912.11770]

- New channels to match expt'l progress at LHCb.

First LQCD calculation of $B_c \to J/\psi \ell \nu$, over the full q^2 range: HPQCD [2007.06956]





Gives SM prediction $R(J/\psi) = 0.2601(36)$ to compare with LHCb $R(J/\psi) = 0.71(17)_{(\text{stat})}(18)_{(\text{syst})}$ [1711.05623]

Conclusions

- Great deal of experimental progress is expected in the near-term horizon for $b \to c$ transitions.
- Expect a rich phenomenology that can shed light on the anomalies in this sector.
- Robust theory effort is needed that can match experiment in
  - Precision - $B \to D^*$ over full kinematic range.
  - Scope - Newly available channels $B_{(c,s)}$, $\Lambda_b \to \Lambda_c$
- Progress is being made in these directions with several new and planned calculations by US and international collaborators.
  - Inclusive B decays LOI TF 020 talk by W. Jay
  - BSM searches LOI RF 047 talk by A. Kronfeld
  - b and c physics LOI RF 068 talk by O. Witzel